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FY15 ASC L2 Milestone #5320: Verification and Validation Propensity Improvements via Solution Verification Automation

Presentation Package (Part 1 of 2)

Matt Staten & Brian Carnes

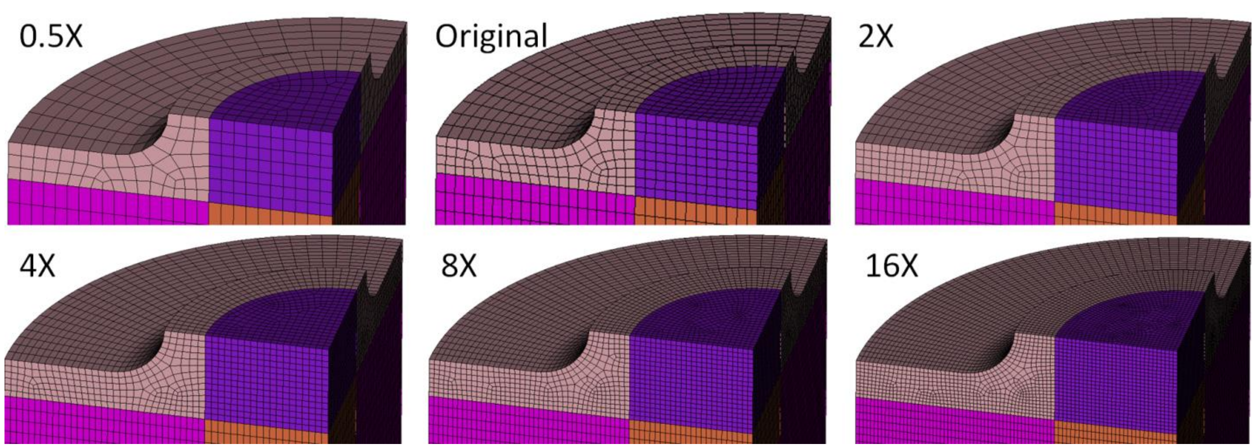
Sandia National Laboratories*

This set of annotated viewgraphs with executive summary provides a record of the completion of FY15 Level 2 Milestone #5320

Executive Summary

A new tool, called Mesh Scaling, for producing series of hexahedral meshes suitable for solution verification was enhanced and hardened by this milestone. In addition, solution verification using the meshes produced from Mesh Scaling was performed and documented. We conclude that Mesh Scaling now produces meshes suitable for solution verification, while offering a substantial decrease in the computational cost of solution verification.

Solution verification has historically been too expensive, depending upon an 8X multiplier in the number of elements between each mesh in the series (8X, 64X, 512X). The 8X multiplier results in too few meshes with too many elements, making solution run-times infeasible. In contrast, Mesh Scaling modifies existing hexahedral meshes, increasing or decreasing the element count globally by any multiplier, producing a larger series of meshes, with fewer elements (0.5X, 2X, 4X, 8X, 16X, etc.) allowing analysts to employ solution verification at a much lower computational cost.



Progress on this milestone was monitored by a panel of Sandia V&V experts, NW analysts, and algorithm experts including William Rider (1446), Kevin Long (1554), Nicole Breivik (1554), Nathan Spencer (8259), and Karen Devine (1426). Quarterly update meetings were held to update the panel and solicit their feedback and direction. The final presentation to the panel was held on Monday, August 24th, 2015, at which the panel confirmed that the team has successfully completed all the criteria associated with the milestone description.

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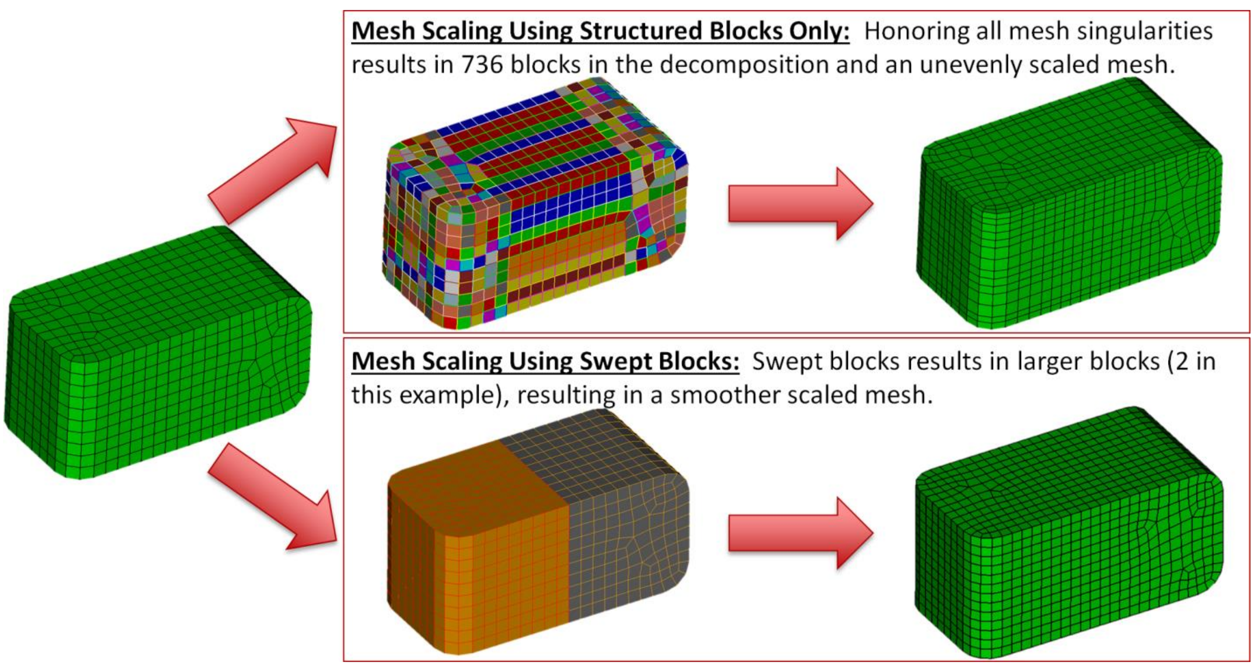
There were three specific deliverables achieved as part of this milestone. First, a robust parallel-ready implementation of the Mesh Scaling tool was completed. Mesh Scaling satisfies mesh queries through a generic API, allowing it to be linked into any FE infrastructure, and accessing any mesh database. This API was implemented for both the Cubit and Sierra (STK) meshing databases. Although Mesh Scaling does not yet leverage the parallel infrastructure in Sierra, mesh scaling is embedded into the Sierra environment, interfacing with the massively parallel STK database, primed for use of this parallel infrastructure through future development. Mesh Scaling has also been thoroughly tested on a suite of NW production models to ensure robustness.

The second deliverable was to provide solution verification convergence trend understanding to facilitate practical use. Solution verification using uniform mesh refinement is inefficient and failure prone; in contrast, mesh scaling enables more efficient and robust solution verification. This requires care in selection of the mesh scaling factors, monitoring of mesh quality statistics, choice of the meshes to include in extrapolation, and the extrapolation process used.

Using several examples we demonstrated that we could use the meshes produced by Mesh Scaling to estimate the numerical error in a number of important quantities of interest (QoIs). In all cases where the QoI had been previously verified, the solution verification was successful. A few QoIs did not appear to converge, but these lacked prior code verification evidence. All of the example problems have been made available in the Sierra regression test suite.

The final deliverable was to investigate and implement techniques to provide globally smooth distribution of refinement. The first step in Mesh Scaling is to extract the *block decomposition* of the input mesh. The block decomposition data structures and construction were enhanced to support swept blocks, in addition to the standard structured (i.e. gridded) blocks, resulting in fewer blocks in the decomposition, allowing for a smoother distribution of elements.



The success of this milestone has changed the manner in which analysts should view solution verification. Solution verification is no longer too expensive due to the now available larger series of meshes with fewer elements, and the enhanced solution verification techniques.